COOL CODES FOR HOT CHIPS:

A QUANTITATIVE BASIS FOR MULTI-CORE DESIGN

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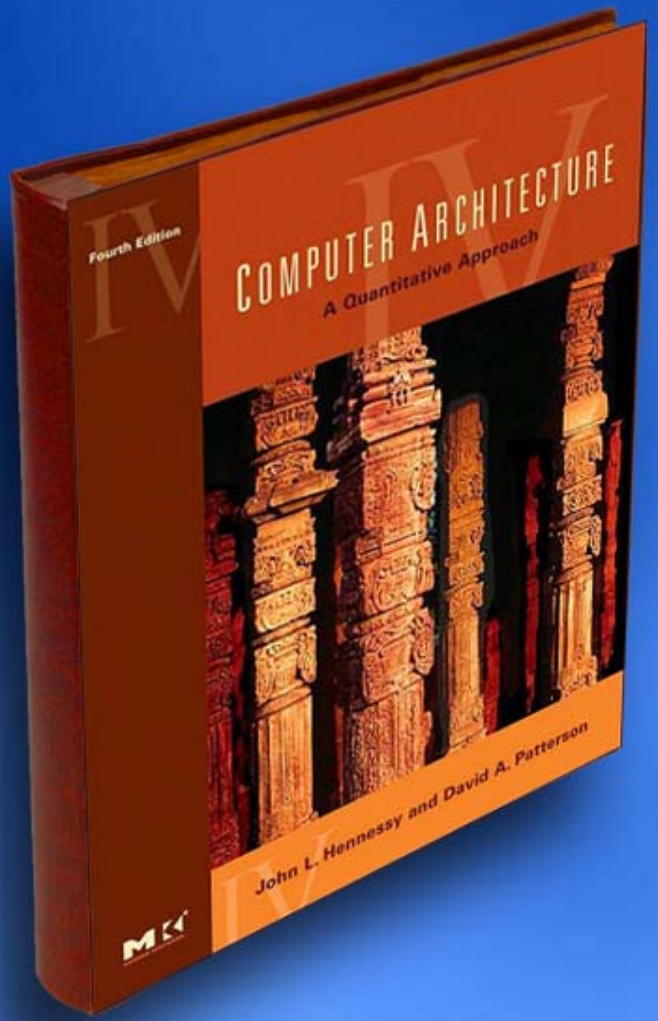
Two Decades of Quantitative Design



intel inside pentium PROCESSOR

TPC Transaction Processing Performance Council

spec

intel inside pentium 4

SYSmark 2004 SE

MobileMark 2005

intel Core 2 Duo inside

3DMARK06 The Gamers' Benchmark

intel

*Third party marks and brands are the property of their respective owners

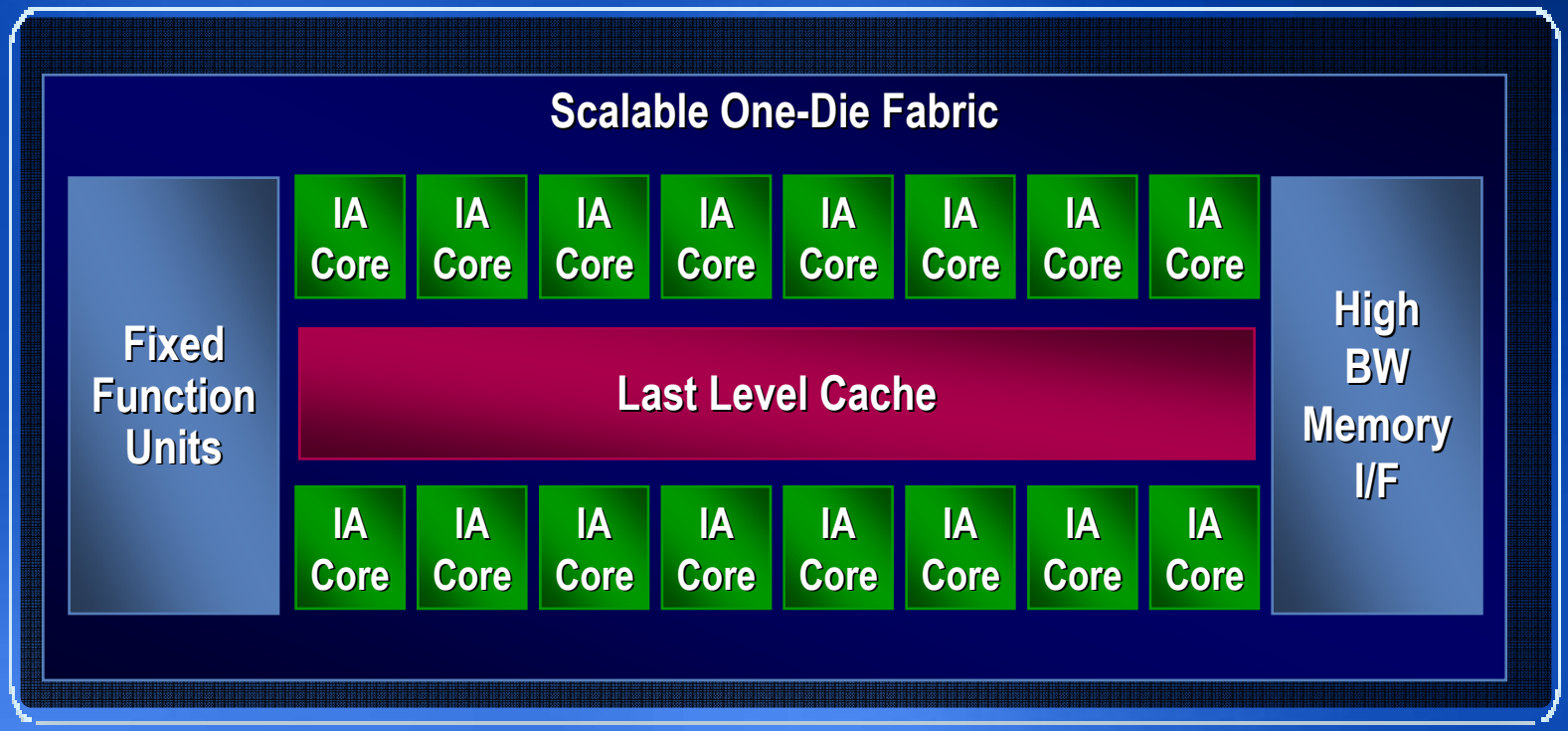
Multi-Core Transition Accelerating

"We notified customers we're pulling in both the desktop and server (launch) of the first quad-core processors into the fourth quarter of this year from the first half of 2007"

"The UltraSPARC T1 processor with CoolThreads technology is the highest-throughput and most eco-responsible processor ever created."

"Azul has been able to pack an industry-leading 24 processor cores on a single-chip, which means that each processor is able to run 24 simultaneous parallel threads"

Tera-Scale Strawman



Opening up new classes of applications

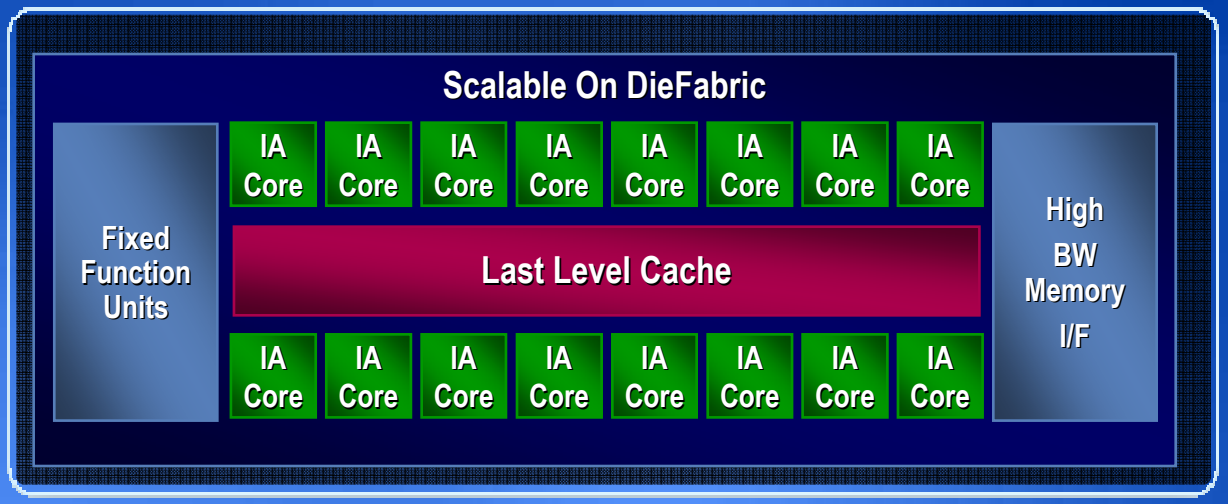
Synthesized output

Source: Intel

Camera 1 input	Camera 2 input	Camera 3 input	Camera 4 input

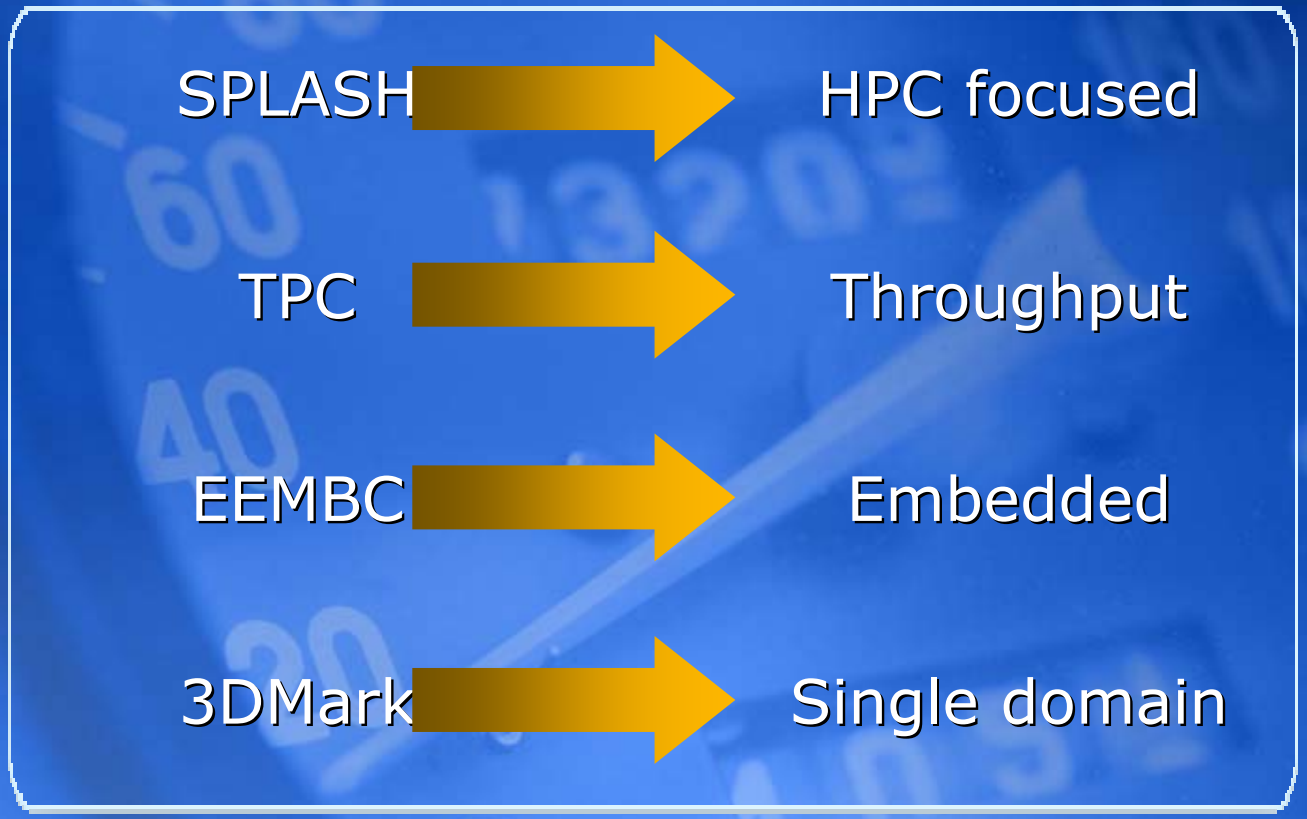
Design Challenges

- Complex memory hierarchy
- Sophisticated on-die fabrics
- Explicit thread support
- Fixed function acceleration

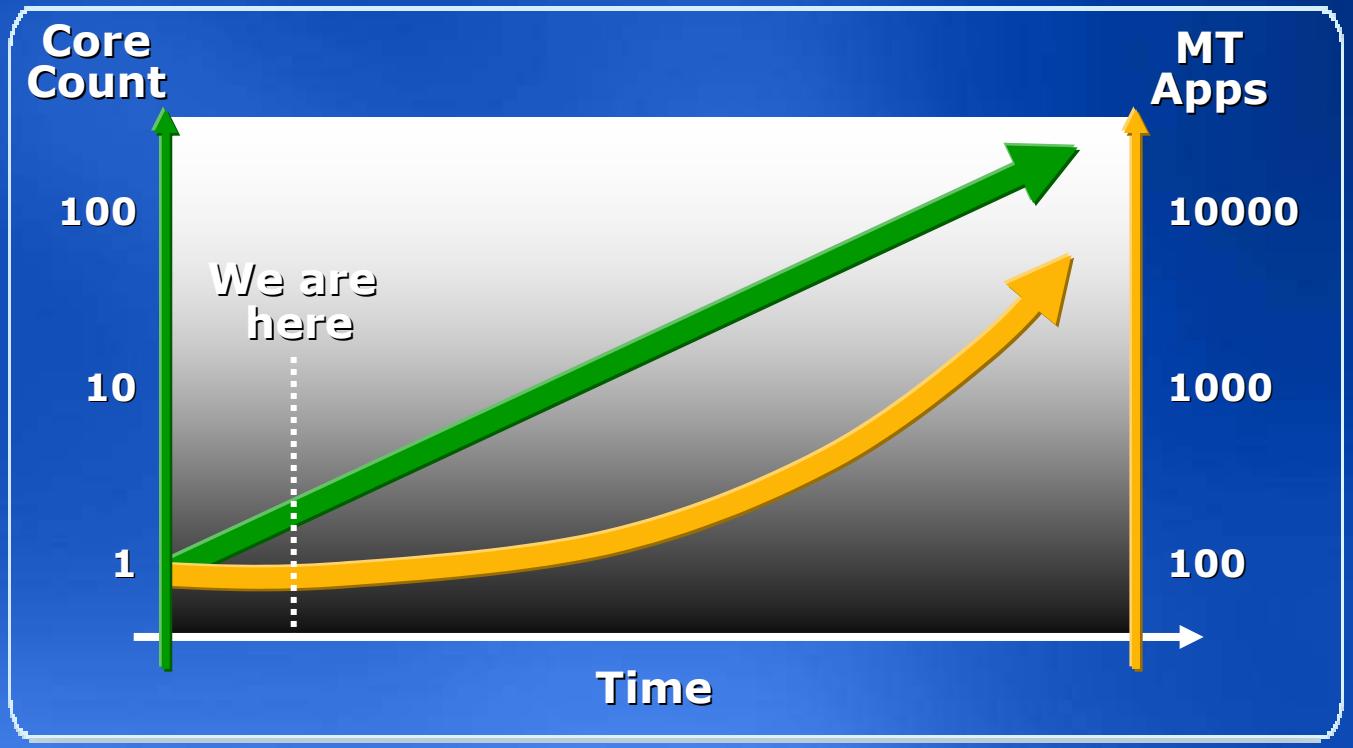


Lacking The Quantitative Tools…

No Multi-Core Metric?



The Waiting Game

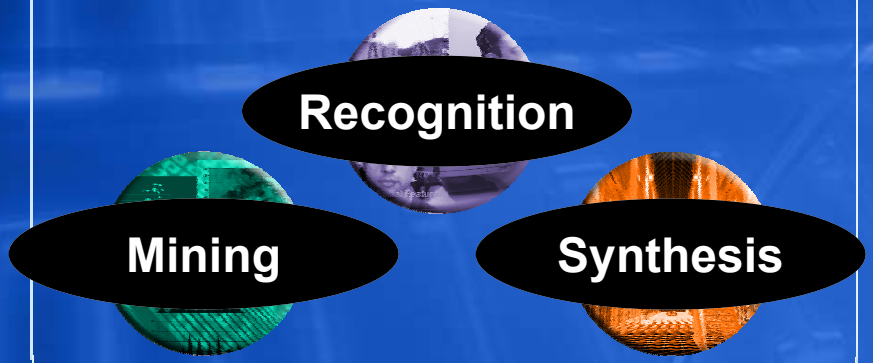


Designing **2010** Processors Today

Must **Anticipate** Future **Applications**

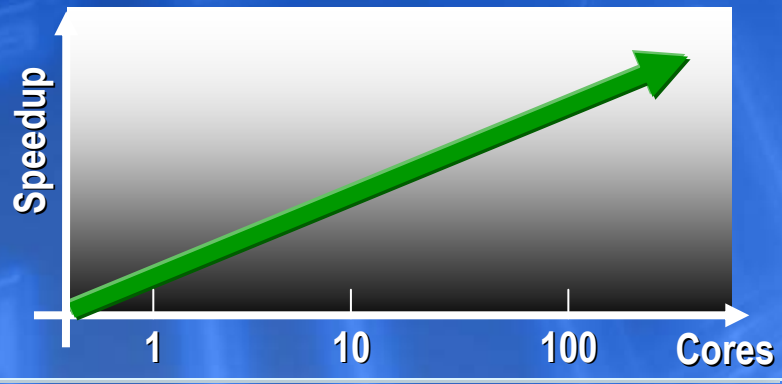
Creating a Multi-Core Benchmark

Established & Emerging

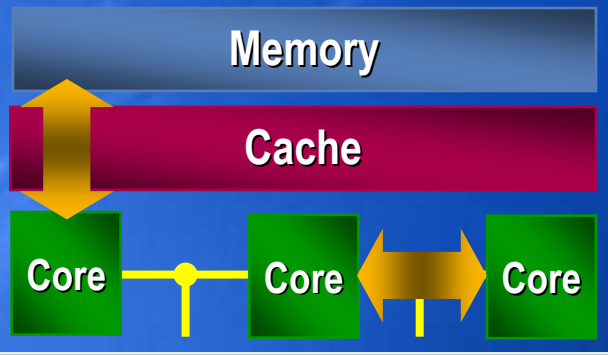


Performance & Energy Aware

Highly Threaded & Scalable



Differentiated and Stressful



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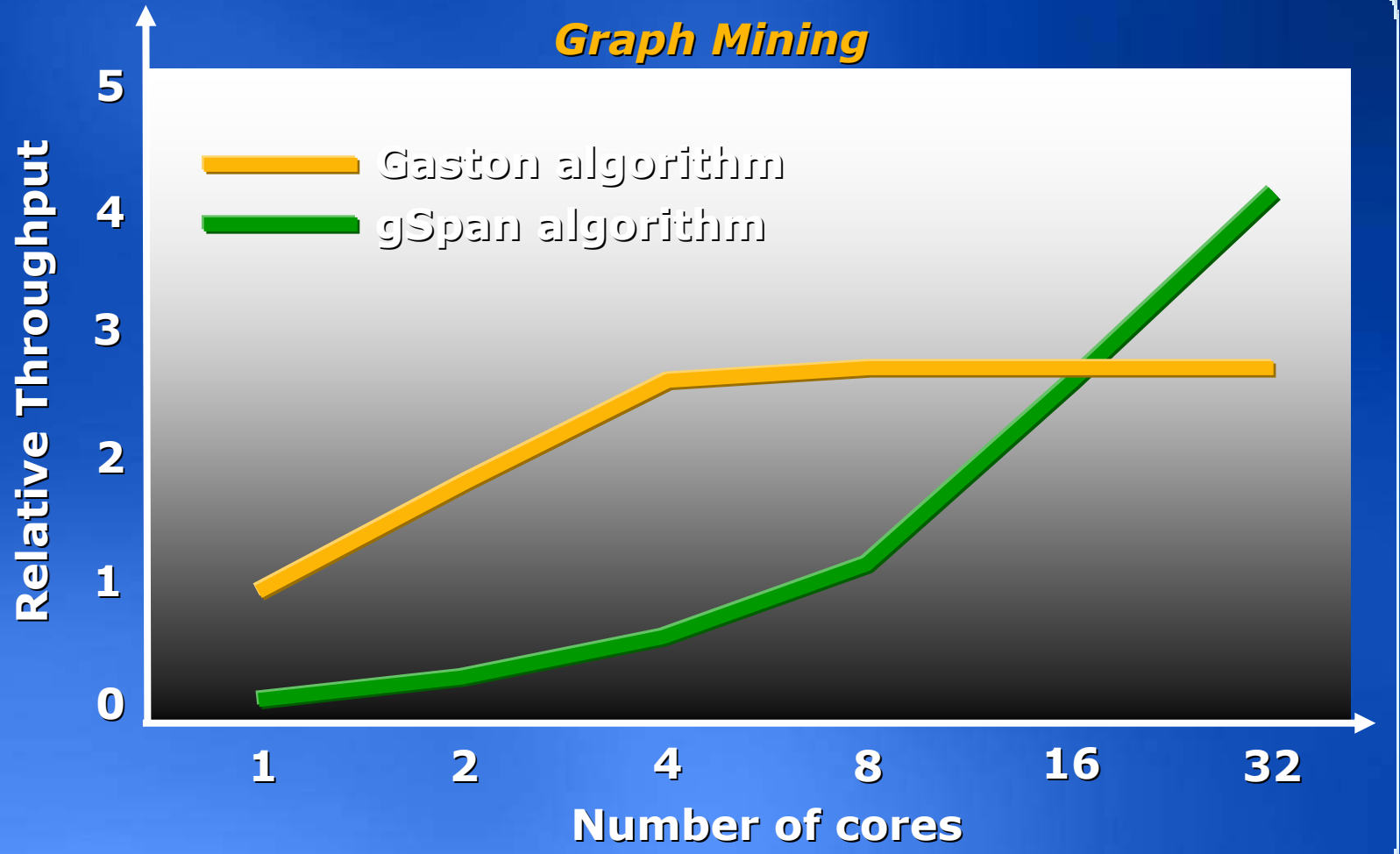
Unique Challenges

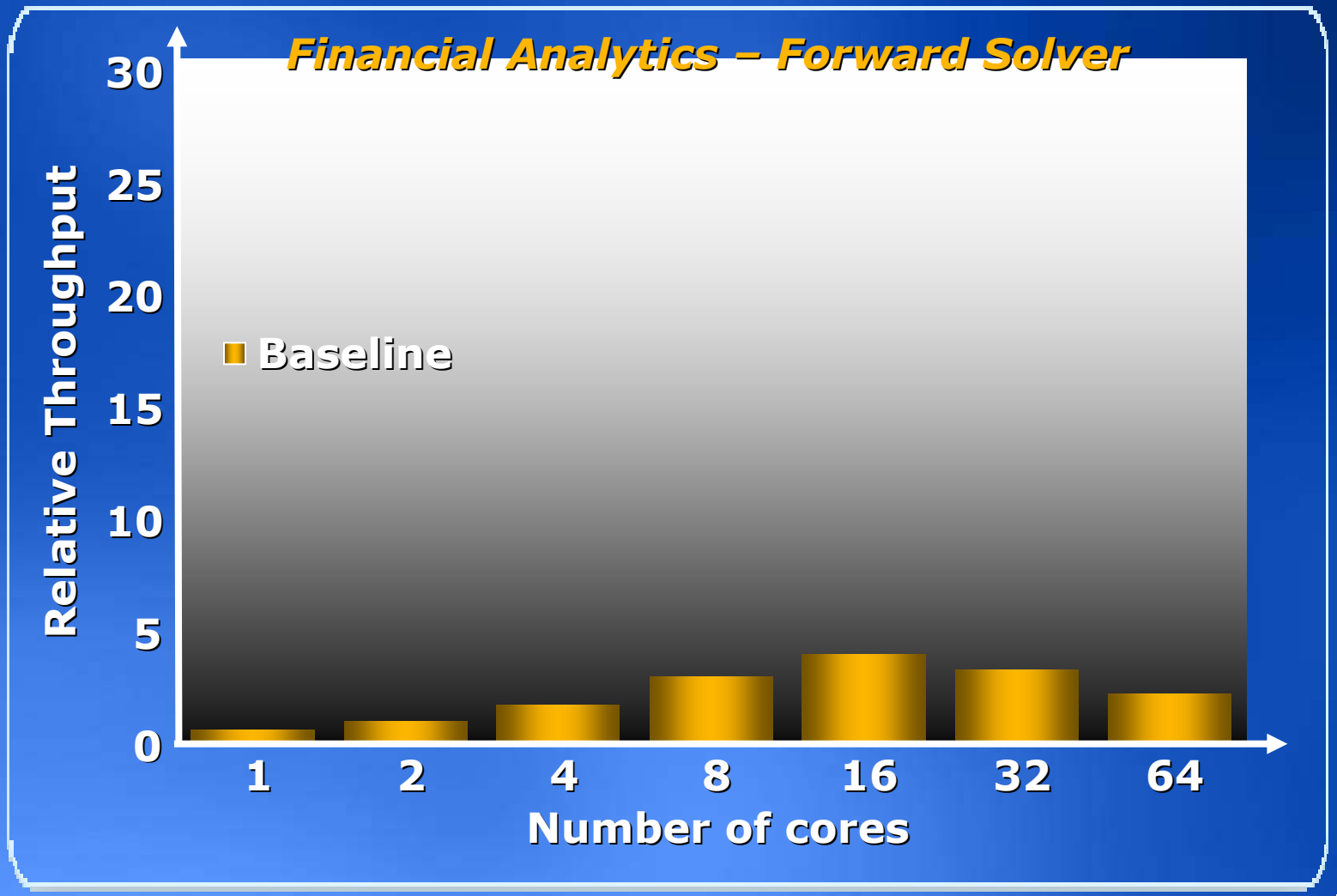
Do We Target…

- Bigger *OR* Smaller Cores
- Performance *OR* Scalability
- Compute *OR* I/O Intensive
- Cache Friendly OR Memory Intensive

Performance vs. Scalability



Architecture-Algorithm Co-Design



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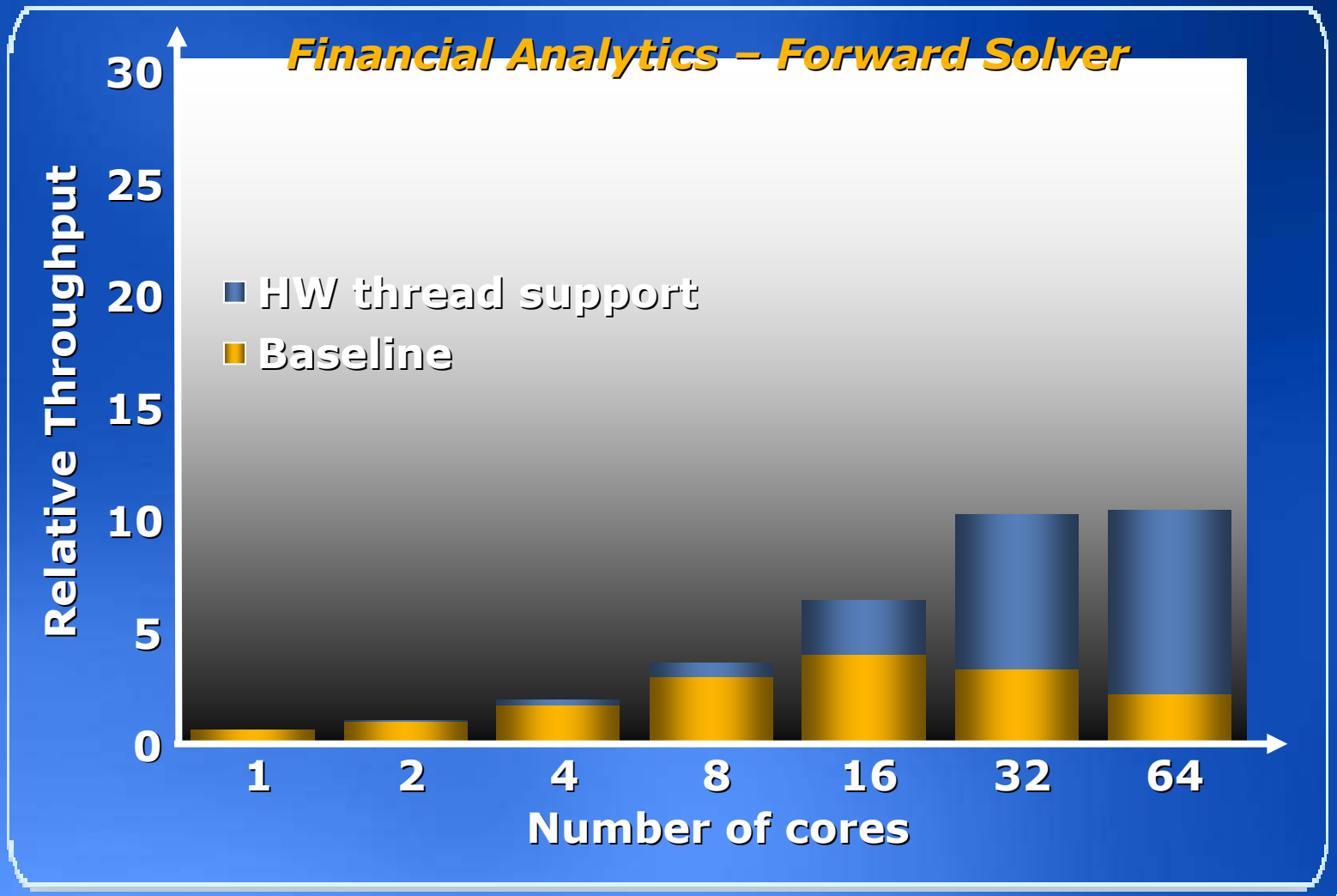

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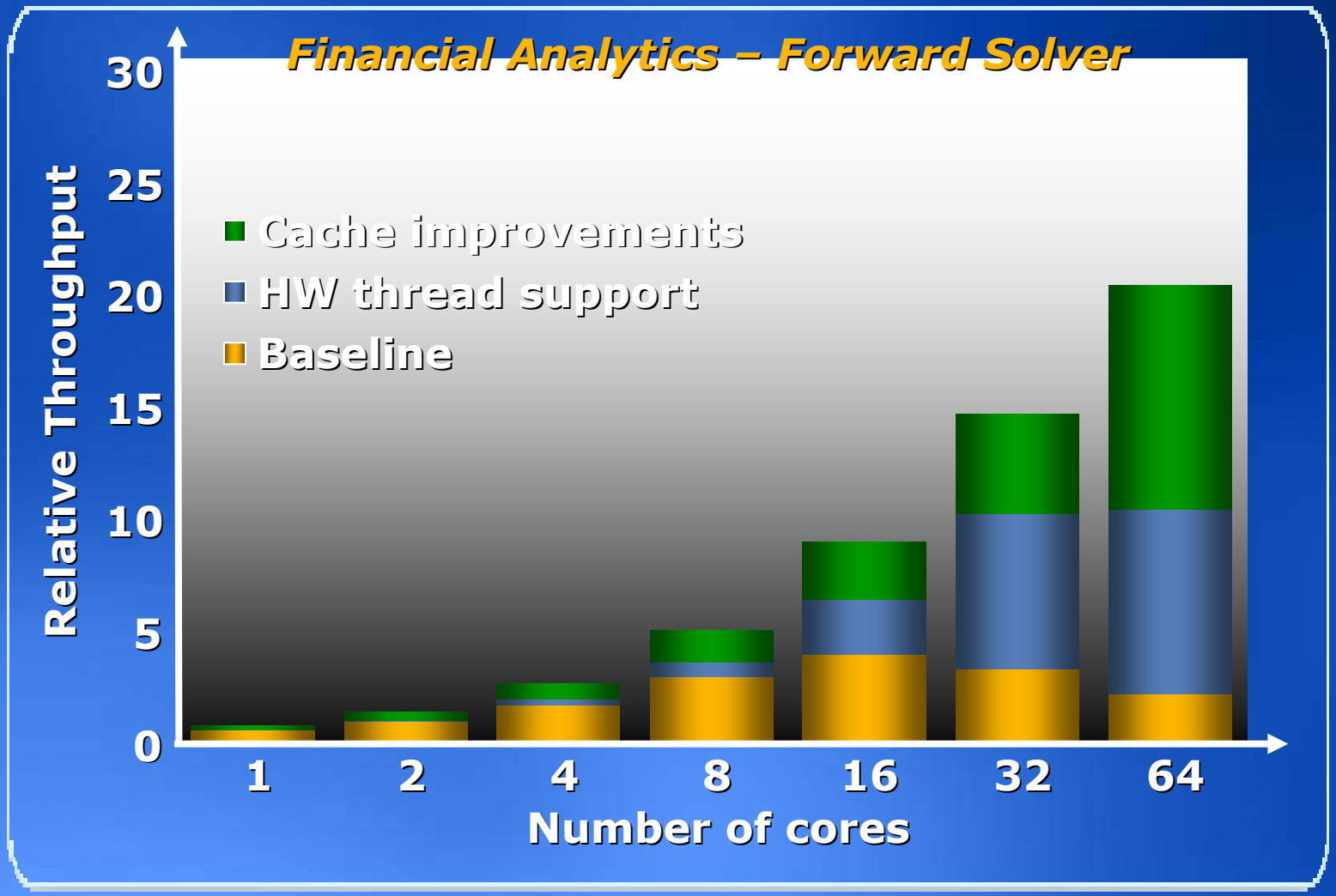
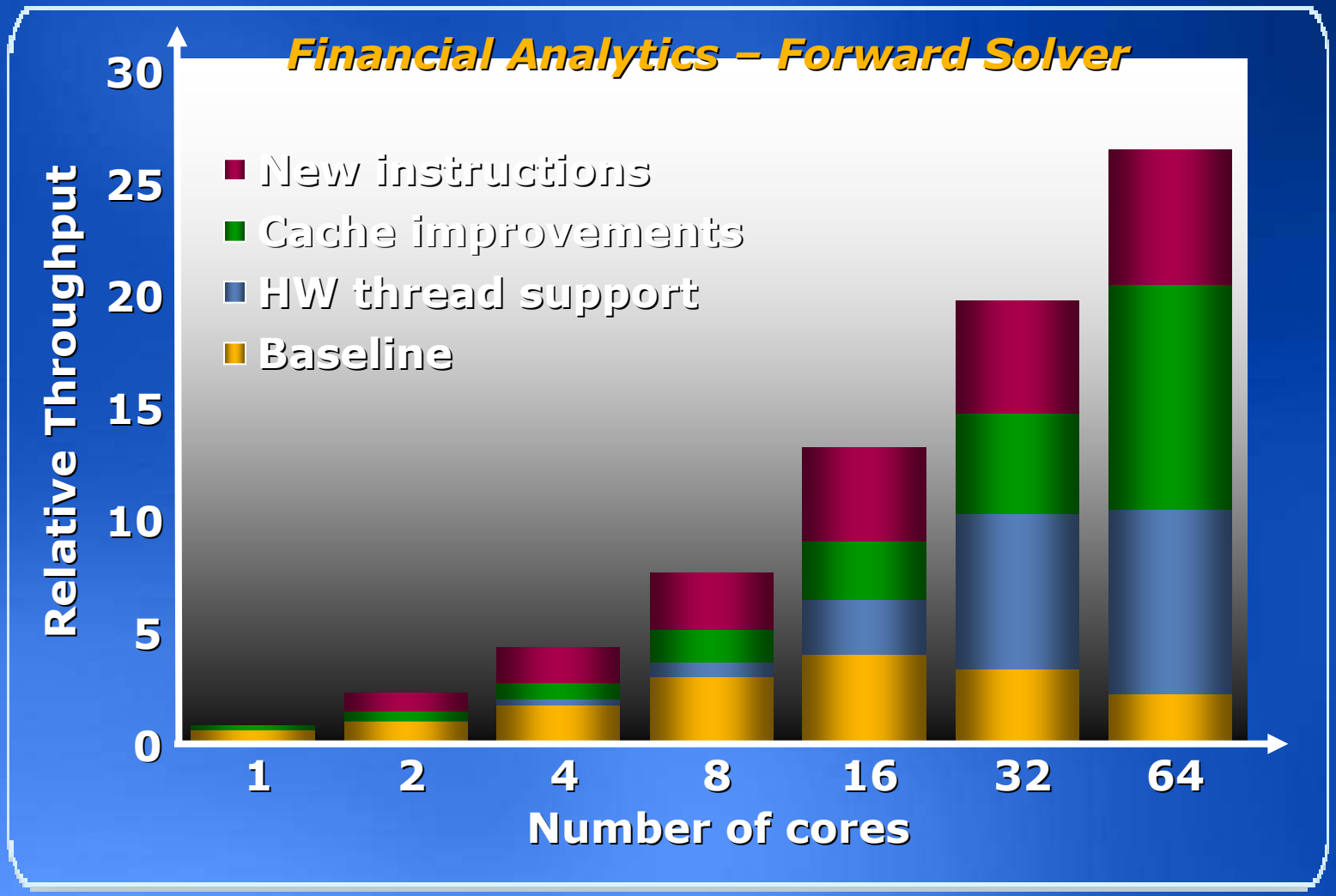


Architecture-Algorithm Co-Design

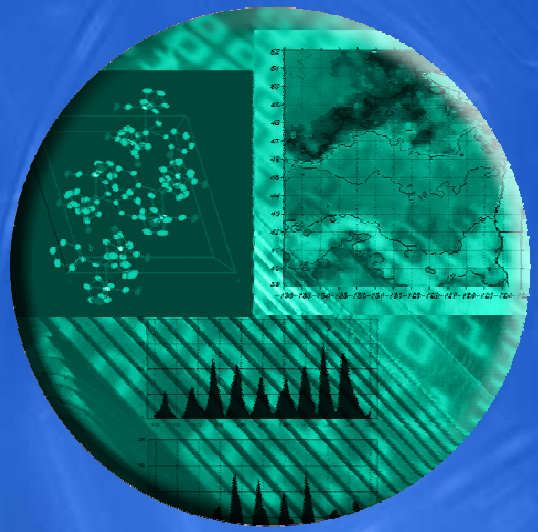


Emerging ‘Killer’ Applications

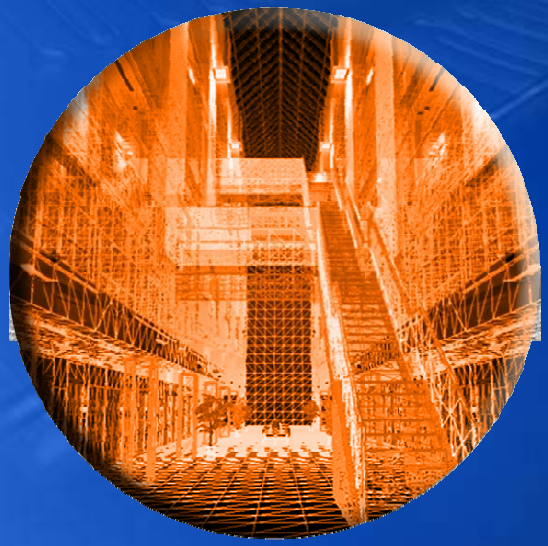
The RMS Suite

Recognition

Mining

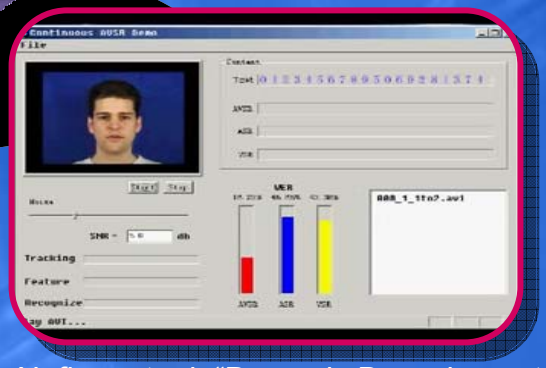


Synthesis



Emerging "Killer Apps" (R)

"What is it?"
Modeling and identifying using multi-modal data

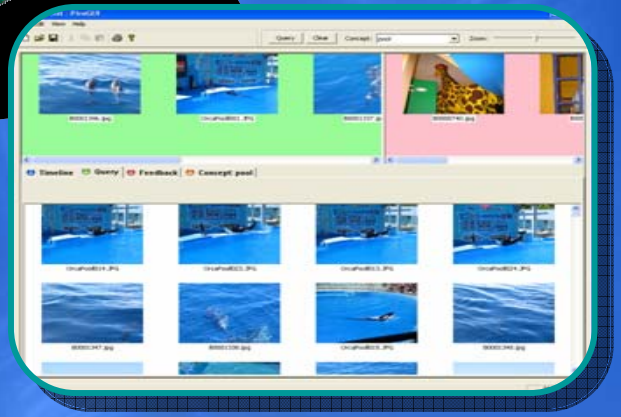


Source: Intel

Nefian, et. al, "Dynamic Bayesian networks for audio-visual speech recognition," Journal of Applied Signal Processing, 2002

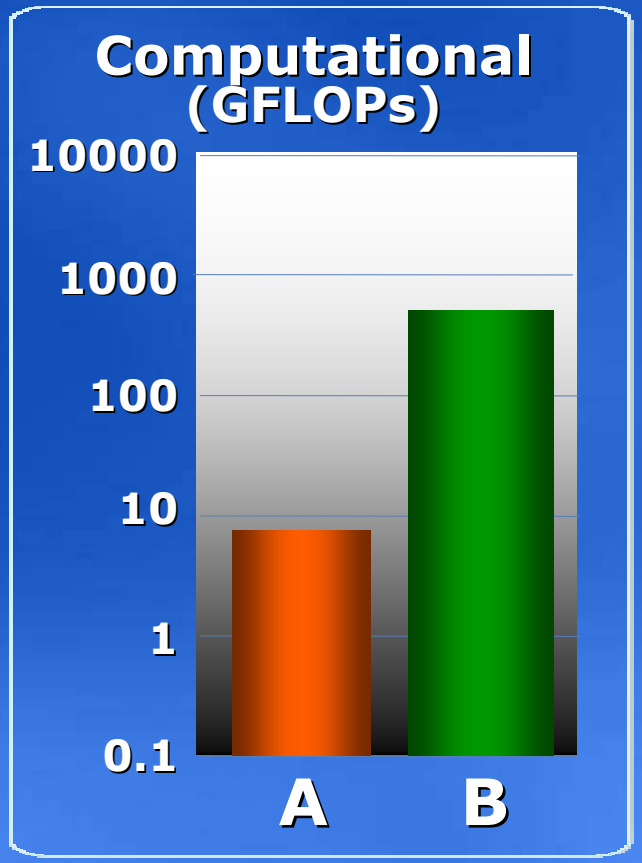
Emerging "Killer Apps" (M)

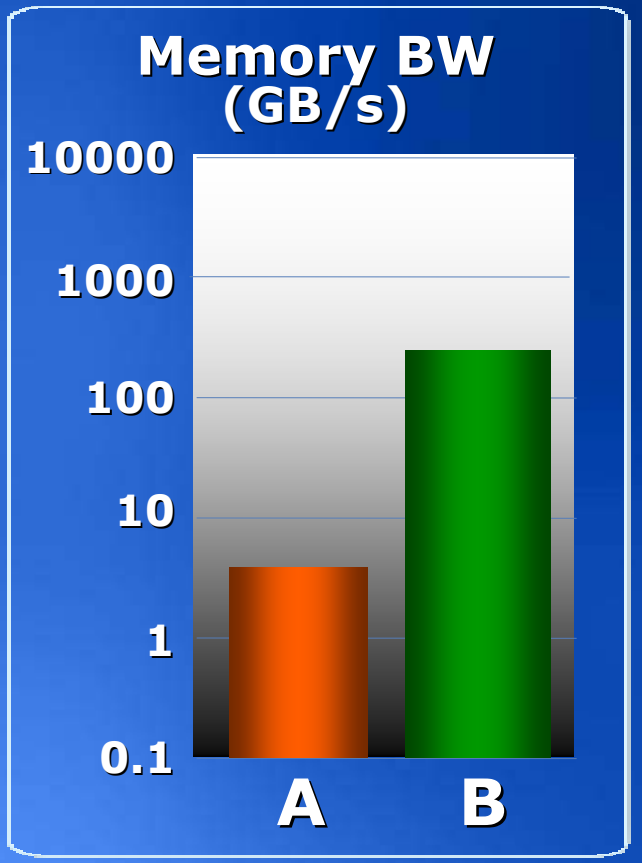
"Where is it?"
Search for a similar instance



Source: Intel

Computer Vision





A: Video surveillance, 2 web cams

B: Body tracking, 4 DV cameras

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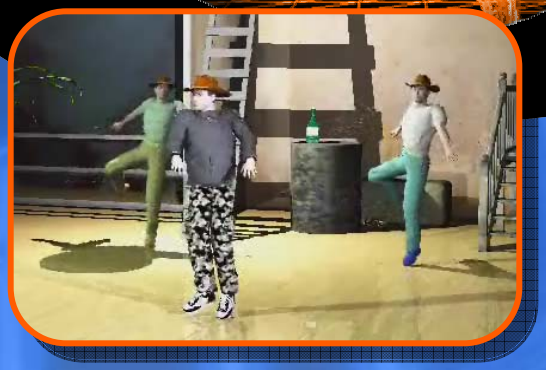
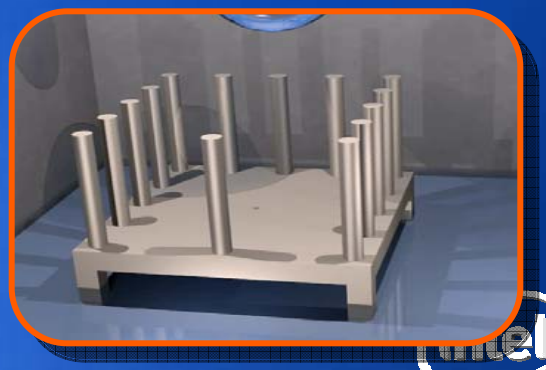
Emerging "Killer Apps" (S)

"What if?"
Creating new model instances



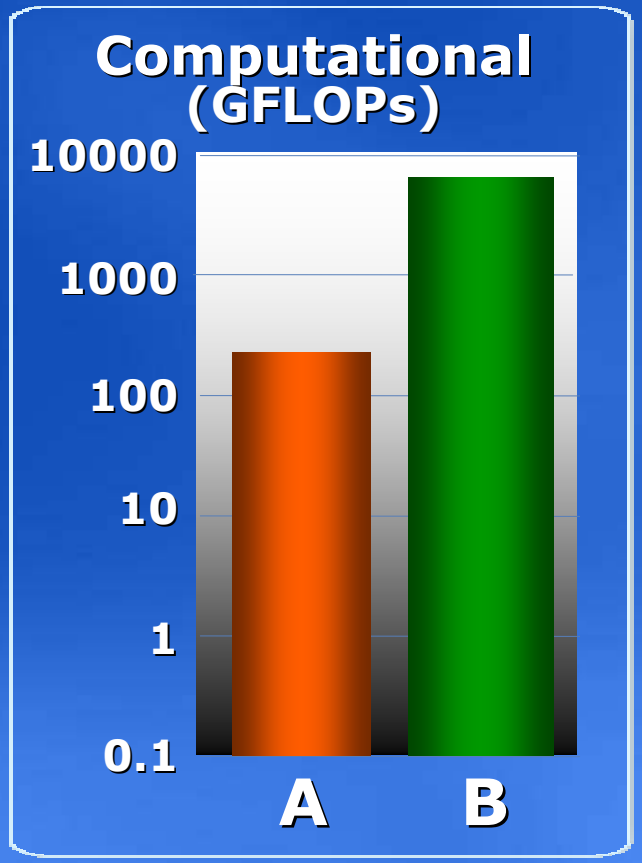
Source: Intel

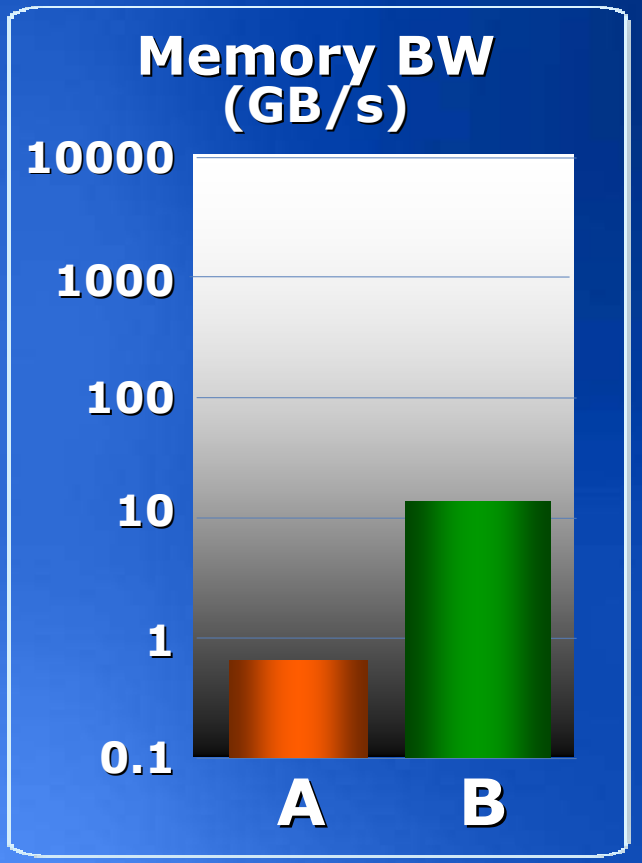
Source: InTrace



Source: Stanford

Ray-Tracing

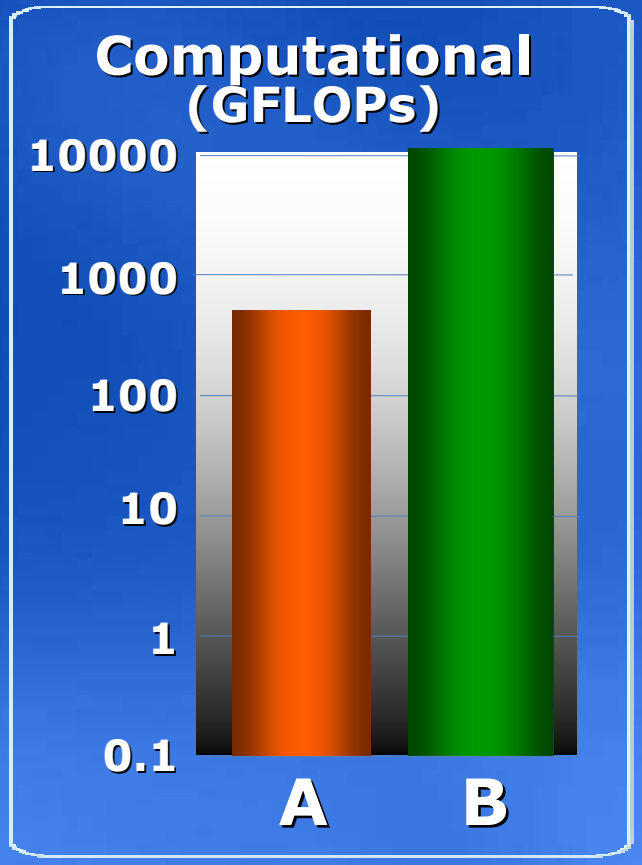


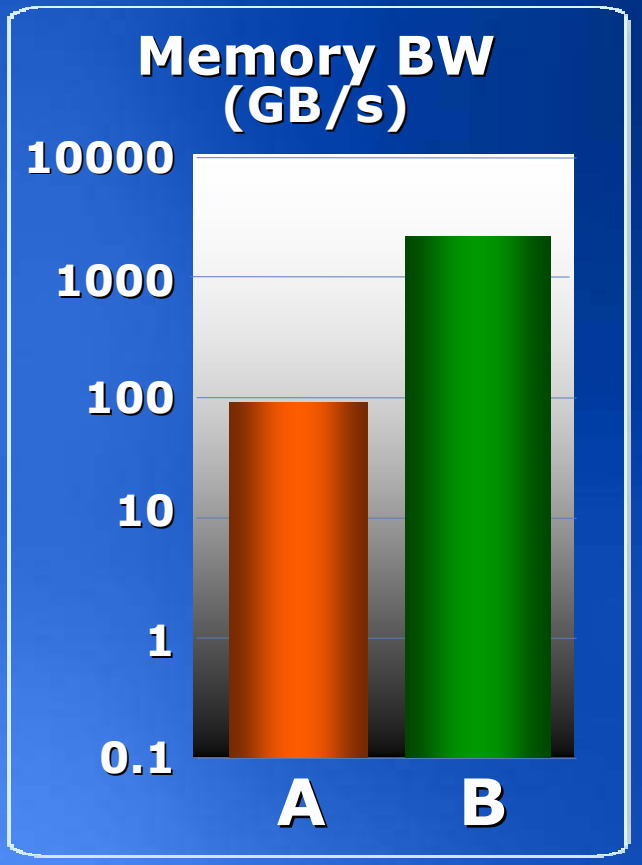


A: Bar scene, 1 mega-pixel

B: Beetle scene, 1 mega-pixel

Physical Simulation





A: CFD, 75x50x50, 10 fps

B: CFD, 150x100x100, 30 fps

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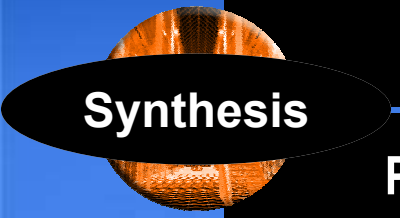
Intel's RMS Application Suite

Ray tracing / Global illumination	Multi-document summarization
Rigid body game physics	Text indexer
Fluid simulation	Mortgage based security valuation
Facial animation	Portfolio management
Cloth simulation	Bioinformatics suite
Full body tracker	Graph mining
Face detection	Frequent itemset mining
Audio-visual speech recognition	Sports video highlight extraction

Intel's RMS Primitives Suite

- Interior point method
- Machine learning primitives
- Signal / image processing
- Numerical integration suite
- Combinatorial optimization
- Finite element/difference/volume
- Partitioning structure collision tests
- Dense matrix primitives
- FG/BG and Canny edge detection
- Sparse matrix primitives
- Convex optimization
- Stochastic optimization
- Partitioning structure build/traversal
- PCG/Jacobi/Gauss-Siedel/PSCR
- Level set/fast marching method
- Black-Scholes/American options

Creating a Public RMS Suite



	Multi-threaded workload suite
Body tracking	☑
Cancer cell detection	☑
Financial analytics	☑
Media search and retrieval	☑
Ray-tracing	☑
Physical simulation	☑
Your workload here	☐

Suite Repository and Working Group

Professor Kai Li
Charles Fitzmorris Professor
Department of Computer Science

Professor J. P. Singh
Department of Computer Science


The Future of Multi-core
Processors is in Our Hands
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Leap ahead™